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Role of Copper in the performance of CdS/CdTe solar cells

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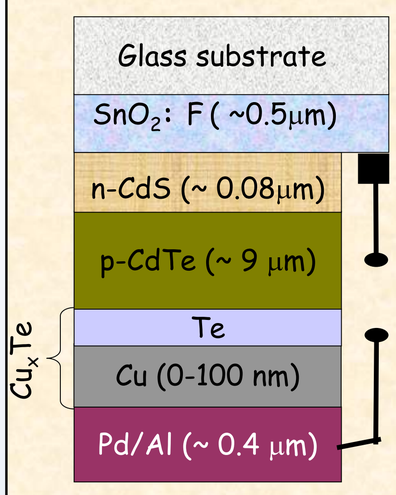
ABSTRACT

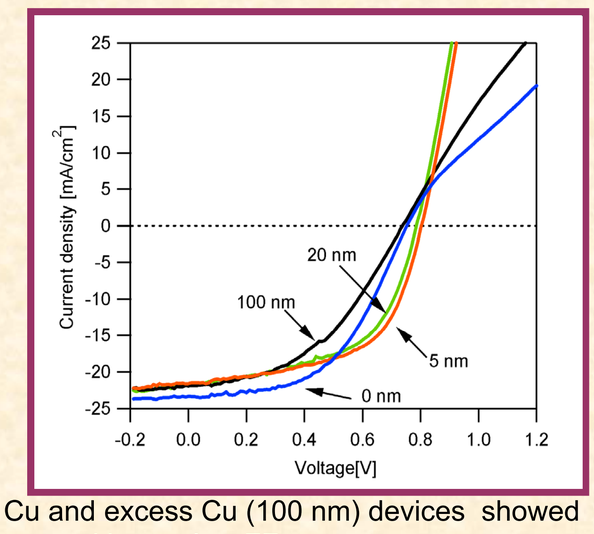
The performance of CdS/CdTe solar cells made with evaporated Cu as a primary back contact was studied through current-voltage (JV) at different intensities, quantum efficiency (QE) under light and voltage bias, capacitance-voltage (CV), and drive-level capacitance profiling (DLCP) measurements. The results show that while modest amounts of Cu enhance cell performance, excessive amounts degrade device quality and reduce performance. The analysis is supported with numerical simulations to reproduce and explain some of the experimental results.

Device structure



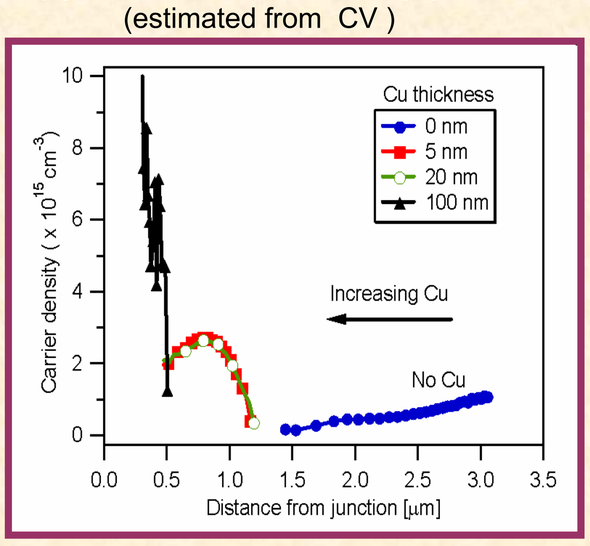
Evaporated-Cu back-contact

JV Characteristics



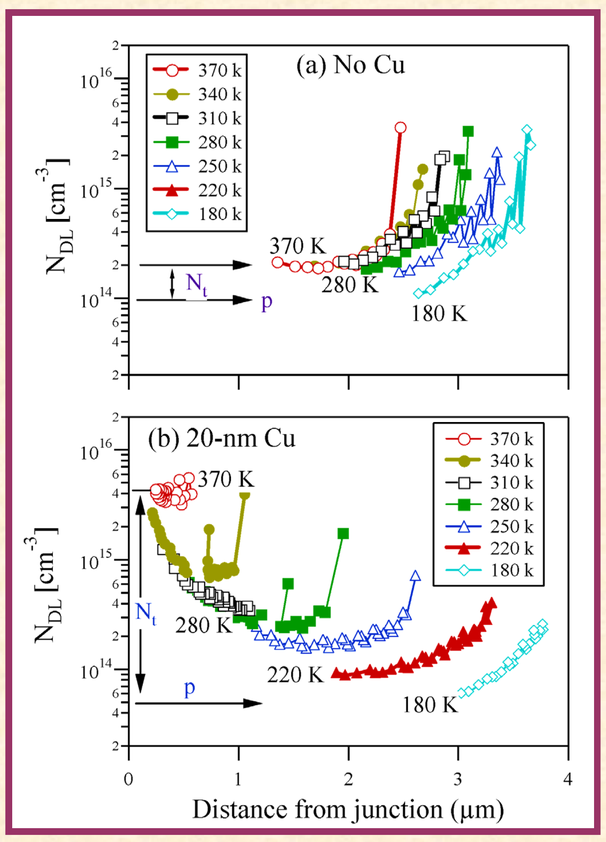
- No Cu and excess Cu (100 nm) devices showed rollover, and hence low FF.
- Parameters of the 5-nm Cu device are: J_{sc}= 21.5 mA/cm^2, V_{oc}= 803 mV, FF=57.5%, and η = 10%.

Apparent carrier density profile
(estimated from CV)



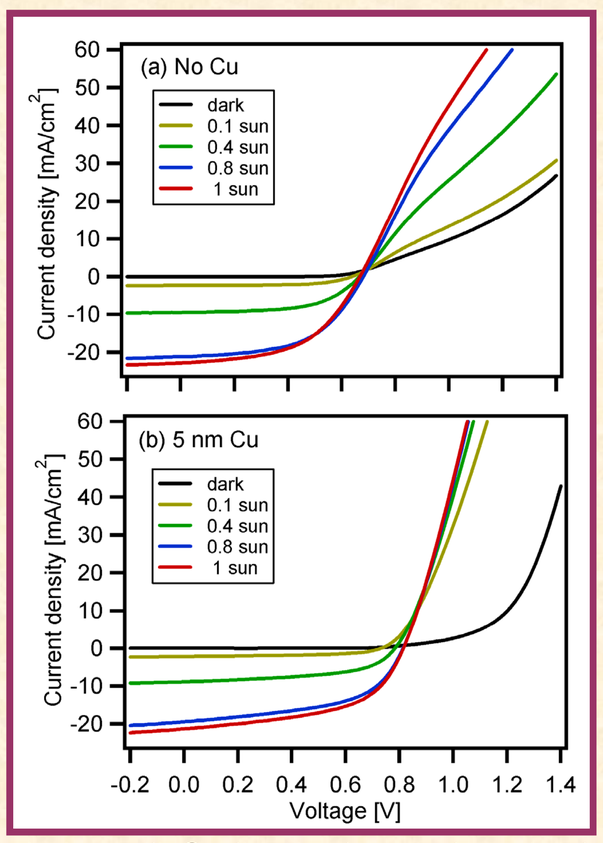
- Low carrier density and a wide depletion width with no Cu.
- Higher carrier density and smaller depletion width with increasing Cu.

DLCP



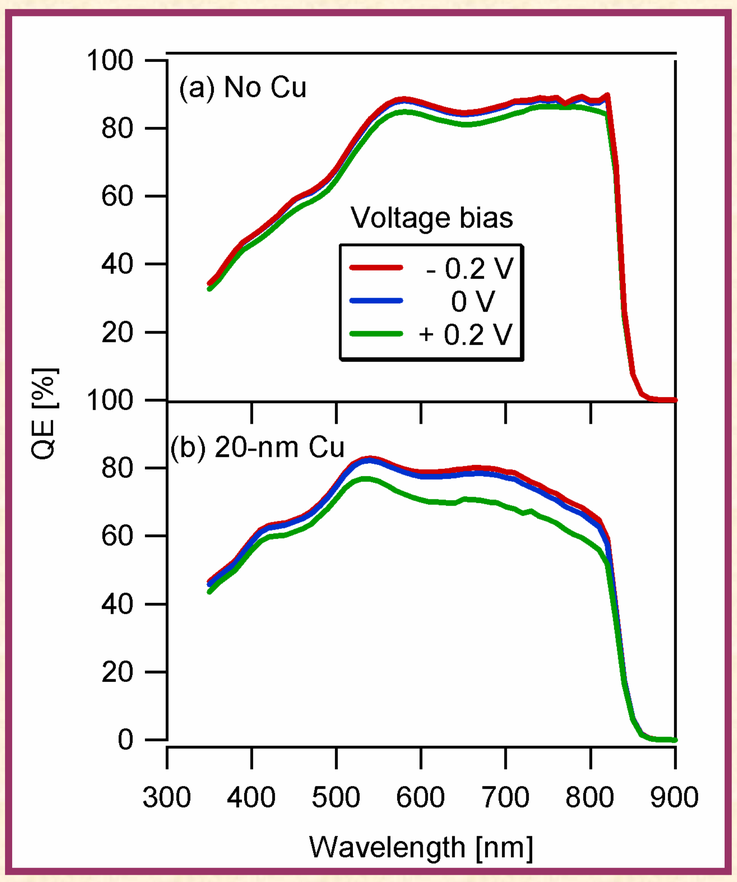
- Density of trap states increased with increasing Cu amount

JV curves as a function of illumination



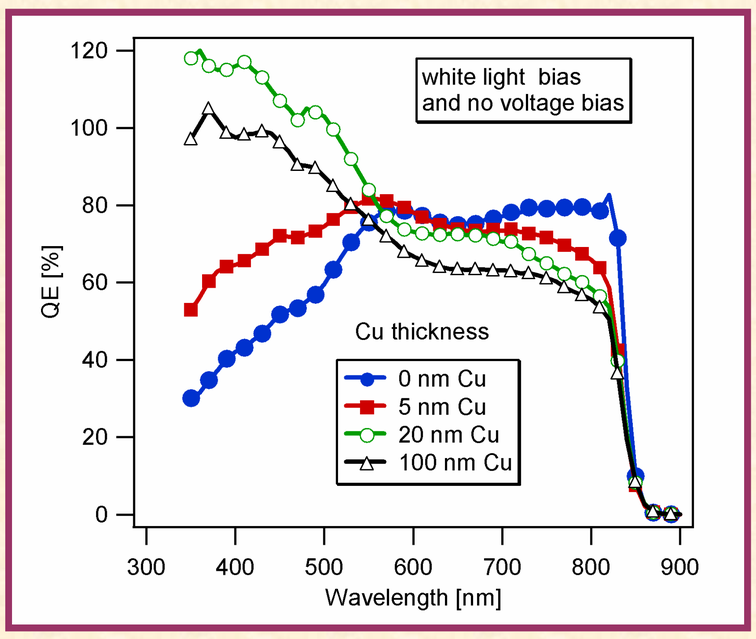
- For devices with Cu, the shunt conductance is intensity dependent, probably due to interface defect states whose occupancy is changed by intensity of illumination.

QE Curves as a function of voltage bias



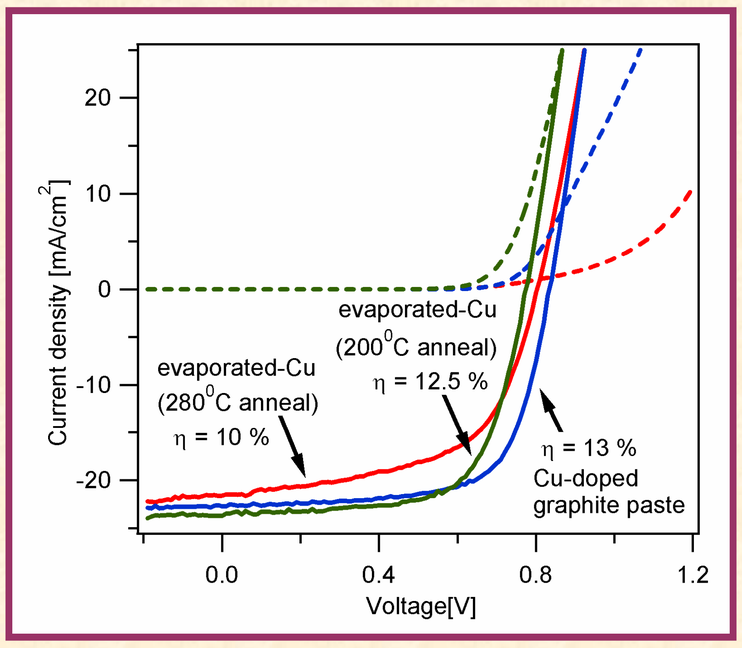
- Minimal voltage dependence when Cu is not used; increasing voltage dependence with increasing Cu.

QE curves under white light bias



- In the blue region (λ < 550 nm), apparent quantum efficiency (AQE) larger than unity under white light illumination is observed in the presence of excess Cu.

Comparison of JV curves



- Comparison of devices made with evaporated-Cu contact (annealed at 200^0 C and 280^0 C) relative to a Cu-doped graphite contact (annealed at 280^0 C).

Conclusions

-Cu clearly enhances device performance, but excess Cu can lead to significant current losses.

- Cu increases the acceptor density in CdTe, however, Cu also forms defects that lower the lifetime, and hence reduced V_{oc} and FF.

- The presence of Cu in the CdS layers is responsible for the crossover and AQE effects. The impact on actual device performance, however, should be minimal.

- The performance of device made with evaporated-Cu contact (annealed at 200^0 C) is comparable to that of devices with the standard Cu-doped graphite paste when the same absorber is used.

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